RDT

Brief

Research Investigation 93-007

July, 2003

MoDOT Application of Maturity Technology

Introduction

When MoDOT repair crews were faced with emergency repair of a heavily damaged overpass on I-70 in December 2002, inspectors looked to the concrete maturity method to facilitate reconstruction operations of one of the structure's northern bents, which was severely impacted in a tractor-trailer accident. The maturity method, a non-destructive means of estimating in-place concrete strength as a function of time and temperature, is recognized as a more reliable and timely method as opposed to testing conventional 6"x12" compressive strength cylinders. Following placement of the bent footings, columns and cap on the I-70 overpass, thermocouples were inserted in the fresh concrete and a maturity value was calculated at desired times. In-place strength was then estimated from a pre-established relationship between maturity values and compressive strength. Application of the maturity method allowed earlier form removal and completion of the I-70 bridge repairs than if concrete cylinders had been used for strength determination. As a result, the bridge was open to traffic several days earlier than anticipated had conventional methods been used.

The Maturity Concept

While the maturity method has been around since the 1950's, it hasn't been until recent years, due to the increasing need to speed up construction operations and improve inspection efficiency, that the method and its benefits have been fully recognized. Based on the combined effects time and temperature have on strength gain in concrete, the maturity method is identified as a simple and reliable approach to estimating in-situ concrete strength in lieu of conventional 6"x12" cylinders. Although representative of concrete delivered to the site, conventional cylinders aren't necessarily representative of the in-situ concrete. Differences in fabrication, curing conditions, and handling of standard cylinders can have a direct impact on tested strength results. However, establishing a relationship prior to construction between mix strength and maturity (computed from its time-temperature history), followed with time and temperature monitoring of the mix during construction, reliable and real-time in-situ strength can be estimated. Application of maturity technology can provide an ideal, non-destructive means of facilitating construction operations including sawing pavement joints, coring pavement, opening pavement to traffic, removing formwork, cold and hot-weather concreting, and others.

ASTM C 1074, the standard practice established for estimating concrete strength by the maturity method, provides two mathematical functions acceptable for generating the strength-maturity relationship or curve for a concrete mix. Depending upon the func-

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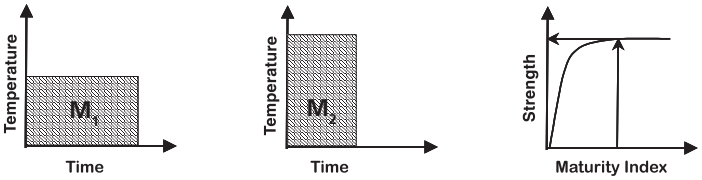
tion used, the maturity index can be determined in terms of time-temperature factor (TTF) using the Nurse-Saul equation or equivalent age (t_e) using the Arrhenius equation. Because of its simplicity and accepted reliability, the Nurse-Saul function using a datum temperature of 14°F (-10°C) is the more widely used, and preferred by MoDOT, of the two equations. To establish the strength-maturity curve, compressive strength is determined from cylinders at various ages along with corresponding maturity values or TTF's for a mix prior to construction. Strength is then plotted against maturity, providing the relationship necessary to estimate in-situ strength. During construction, time and temperature of the placed concrete are monitored and calculated maturity values are correlated to a determined strength using the curve. As a result, timely construction decisions can be made based on more credible information and the labor and guesswork associated with conventional cylinders can be minimized or avoided.



Maturity Concept: $M_1 = M_2$ = Maturity Index

Application on UTW Overlay Placement

While MoDOT's Research, Development and Technology (RDT) program has been familiar with the maturity concept for some time, serious consideration of its application came as a result of recognizing its potential benefits to speed up construction of a fast-track, ultra-thin whitetopping (UTW) overlay in the late summer of 2000. Using maturity technology on the fast-track overlay at the busy intersection of Rte. YY and Belt Highway in St. Joseph provided an excellent opportunity to demonstrate its benefits in the field. Prior to construction of the UTW overlay, RDT staff worked with the ready mix producer at the plant to generate a strength-maturity relationship for the mix to be used. During construction, thermocouple wires were inserted mid-depth in the 3 in. overlay at various locations to monitor time and temperature. Throughout construction, strength of the in-situ pavement was estimated according to the maturity curve, enabling efficient decisions to be made concerning the optimum time to saw joints and to open the pavement to traffic causing minimal disruption.

A maturity meter is checked for most recent maturity values, which will be used to estimate in-place compressive strength on a fast-track UTW concrete overlay in Independence.

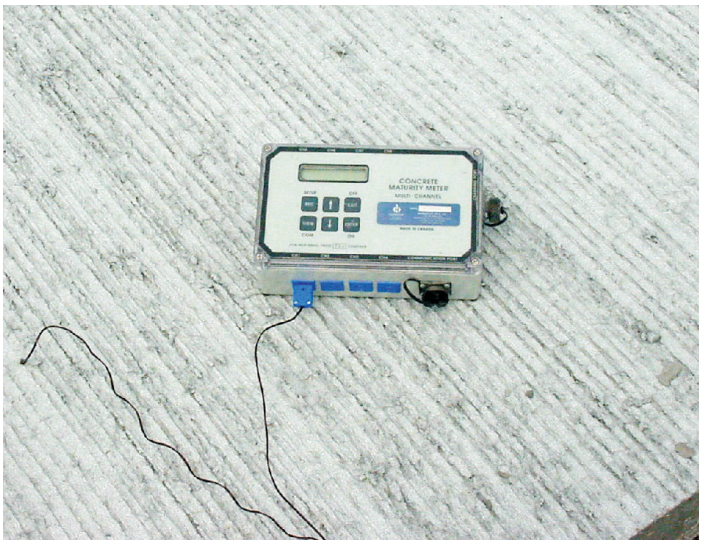
Application of the maturity method on another fast-track, UTW overlay at the intersection of Rte 291 and 23rd Street in Independence was just recently completed. Like the St. Joseph project, a strength-maturity curve for the high early strength overlay mix was established prior to construction. Time and temperature of the newly placed concrete was monitored during construction, and the in-situ concrete strength was estimated according to the curve. As a result, sawing of the pavement joints and opening of the intersection to traffic was handled much more efficiently reducing total construction time.

Maturity Equipment

The maturity method can be conducted simply using minimal equipment such as thermocouple wire and a data logger, where mix time and temperature data are collected then used to manually calculate maturity values. Commercial maturity meters, more sophisticated devices capable of monitoring time and temperature and automatically computing maturity values in terms of time-temperature or equivalent age as desired, even more simplify the use of maturity technology. Commercial maturity equipment has advanced recently to the availability of sacrificial sensors placed in the concrete with wireless transmission of the data directly to inspectors during construction, further increasing the efficiency and effectiveness of the maturity method.

RDT's initial experience with maturity testing equipment included various data loggers and thermocouple wire. Depending upon the type of data logger used, problems were sometimes encountered due to the equipment's sensitivity to extreme ambient conditions (high humidity, heat or cold) and some data loggers were felt to be

awkward or difficult to manage in the field. In addition, values for maturity had to be manually calculated. RDT currently uses commercial maturity meters to conduct maturity testing and have found these devices to be dependable and operate much more efficiently than equipment used in the past.



A maturity meter recording time and temperature of in-place pavement concrete.

Procedure Limitations

While the maturity method is no doubt a valuable tool, it does have some limitations. The following should be kept in mind when applying the method. The maturity method assumes that sufficient moisture is available during cement hydration and, therefore, does not account for inadequate curing. Hence, any variation in strength due to poor curing during construction would not be reflected in the maturity curve. Once the strength-maturity relationship for a particular mix has been established prior to construction, no changes in mix design constituents or proportions during construction should be allowed other than minimal changes within acceptable tolerances. Otherwise, the accuracy of the maturity curve to estimate strength of the mix during construction will be compromised, resulting in an unreliable curve. Early age temperatures of the mix used to establish the maturity curve similar to those anticipated of the mix during construction are also recommended for improved reliability. The maturity method does not take into account any errors in placing and consolidation; thus, good construction practices are essential, as with any project. Each of these issues can and should be easily addressed through good project quality control and should not serve as an obstacle to applying maturity technology.

Future of Maturity and MoDOT

The maturity method has demonstrated itself as a desirable and reliable means of indicating in-situ compressive strength and facilitating construction operations. When procedures are properly followed, maturity can be an exceptional tool allowing timely decisions impacting construction operations. With a specification recently developed and in-place, MoDOT intends for contractors to invest in maturity equipment and conduct their own testing to facilitate work on future projects, as opposed to MoDOT providing the equipment and conducting maturity testing on previous projects. Recently, the new specification was included in the contract for the construction of an unbonded concrete overlay on I-55 in St. Louis, which required accelerated construction and optional contractor application of the maturity method. Application of the maturity method is also currently allowed on MoDOT QC/QA (quality control/quality assurance) paving projects as an option to the contractor for determining the earliest time pavement cores can be retrieved for thickness and design strength verification. As more contractors become familiar with maturity technology and recognize its benefits, future application in Missouri is only expected to increase.

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